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PROFESSOR KLEIN AND TECHNICAL EDUCATION IN GERMANY.

A MOVEMENT regarding the higher technical education in Germany was started a few years ago by Prof. Klein, in conjunction with some of his colleagues (Nernst and others) at the University of Göttingen, which may become a most important factor in the development of technical education as well as of science. It has, however, from the very outset, met with violent opposition, both in University and in engineering circles.

An account of Prof. Klein's scheme, and of the discussion to which it has given rise, cannot fail to be of interest to all concerned with technical education.

The first publication of Klein's on this subject is contained in the lithographed memoir dated Easter 1895, and which has been published in the *Zeitschrift des Vereins Deutscher Ingenieure*, January 1896. In it is proposed the establishment of a physico-technical institute at the University of Göttingen.

The object of this institute he states to be to give opportunity to persons who already possess a certain amount of scientific or technical education to increase both their knowledge and their power of using it.

It is not intended for the education of large numbers, but rather to help the exceptional few who, in consequence of their talents or other favourable circumstances, can spend more time on their education.

Or, as it stands in the original—

"Das zu gründende Institut soll wissenschaftlich oder technich bereits bis zu einem gewissen Grade vorgebildeten Personen Gelegenheit zu weiterer Vertiefung ihres Wissens und Könnens auf physikalisch-technischem Gebiete liefern. Hierbei wird es sich nie um Massen ausbildung, sondern nur um die Förderung einiger Weniger handeln, denen Talent oder sonstige glüchliche Umstände ein Uebriges auf ihre Ausbildung zu wenden gestatten."

The projected institute should combine all the appliances of modern physics with those technically used, but so that the first are subservient to the latter.

In physics the study of nature is nearly always conducted with experiments carried out in the smallest dimensions, whilst the engineer works towards the mastery over nature on the largest scale. The institute should combine both *micro-* and *macro-physics*.

The following are given as the more important departments of the institute: "Precisions-Mechanik" (measuring instruments); theory of elasticity and strength of material; kinematics, including hydraulics and experimental ballistics; practical thermo-dynamics and practical electricity.

It is added that it will scarcely be possible to establish all these at once.

Lectures of a practical nature are to be added on all the subjects.

The importance of practice in drawing and construction is also dwelt upon. The chief thing, however, will be the work in the laboratory.

It is pointed out that this scheme will enable the engineer to take a University degree by a scientific thesis on some technical subject.

The qualifications of a director and an estimate of the necessary expenditure are next discussed. The latter is put down at about 15,000*l.* as the initial expense, and the annual cost as 750*l.*, exclusive of the director's salary.

Then follows a more minute discussion of the plan and its relation to the Reichsanstalt in Charlottenburg, its connection with the University, the advisability of such an institute from the engineer's point of view, the benefit it will be to the University, and the suitability of Göttingen for such an institute.

The first thing which will strike every one in reading this will be that there is nothing more proposed here than is, or might be, carried out in many of the higher technical schools, and that the whole has been devised at the University somewhat in ignorance of what the technical schools are doing. Nothing, therefore, seems more natural than that from these a unanimous voice against it should have been raised. Klein himself has fully acknowledged this defect in this first statement of his scheme.

To form a true idea both of his high aims and of their importance for technical education, it is necessary to enter into the criticism already mentioned, which the plan has received from engineers and engineering professors, and into a number of further publications by Klein on the subject, mostly addresses read at meetings of engineers and teachers.

A perusal of these papers brings out clearly the following points.

There has grown up in Germany a strong feeling of antagonism between the technical high schools ("Technische Hochschule" is the name now generally given in Germany to the colleges devoted to higher technical education) and the Universities. The new life infused into Germany since its unification, and the great impulse given thereby to German industries, has naturally had its influence on the technical high schools and on technical education in general; but the Universities have remained almost uninfluenced by it. They have remained stationary whilst the others have progressed, and the engineers have more than ever looked with sovereign contempt on these ancient and, to their minds, fossilised seats of learning.

But their progress has been hampered by the unsatisfactory preliminary preparation of the students on entering on their technical studies, and so the whole question of secondary education comes in, just as it does in England. To remedy this, and make the school teaching less classical, and to bring it into closer connection with the requirements of modern life, the technical high schools now claim that the teachers of mathematics and science should be educated by them, and not at the Universities. At the same time, they feel the need of attaching to themselves, or where they exist already to extend, just such laboratories as Klein described, and they maintain that these can only be useful to the development of industry if they are under their direction, and further, that any money given by the Government to the Universities would be taken from *them* and utterly wasted.

There has also been going on a gradual reformation in the programmes recommended to the students, and an endeavour to restrict the purely theoretical parts, and to dwell more on the increase of power in the students to apply their knowledge instead of increasing the knowledge itself, and altogether to bring the teaching into closer connection with practical needs; to increase the *Können* as opposed to the *Wissen*.

It may be mentioned here that the engineering course in Germany extends over four years, and the students generally enter about the age of eighteen, having, as a rule, spent one year at works beforehand; so that they do not enter practical life till they have, on an average, reached an age of about twenty-three years or more, as the year of military service has to be taken into account. Even then those who want to enter into the service of the State are tied down by the necessity of passing a final examination at about the age of twenty-seven.

It is felt that this age is altogether too high, and to remedy this requires, in the opinion of the technical professors, that the students should be better prepared at school, so that the more elementary part of mathematics and physics can be left out of their course.

The most active of these technical professors is Prof. Riedler, at Charlottenburg, who is well known in this country as a successful practical engineer. His plans for reform have been published in the *Zeitschrift*, 1896, and from recent numbers of the same periodical it becomes apparent that his proposals have in the main been carried out at Charlottenburg. In reading through these, one thing is very striking: a great deal of what he writes on the aims of the highest technical education might have been written by Klein in favour of his plans; in fact, Riedler lays it down as a necessary duty of the technical high schools to care for the highest scientific education of a few engineers.

He says already in 1895 (*Zeitschrift*, August 10, 1895), after discussing the needs of the average students, "Die Hochschule muss jedoch mehr bieten, sie muss einer beschränkten Zahl wissenchaftlich Begabter die höchste Stufe Mathematischer Bildung zu erwerben; aber diese muss eine fruchtbare sein und kann erst dem Fachwissenschaftlichen studium nachfolgen

"Die Universität Leipzig hat angeblich diese höchst zeitgemässe Aufgabe erfasst, sie wäre aber für die Technische Hochschule näher liegend. Wo sollen die Universitäten ins gesamt auch nur eine Lehrkraft hernehmen, die den Ingenieuren das versprochene und Nothwendige bieten könnte?"

Riedler develops his ideas still further in 1896 in several articles (*Zeitschrift*, pp. 301, 337, 374), and also criticises Klein's scheme, of course as a strong opponent.

From these quotations it is clear that he feels the same need for the highest technical education as Klein; but we may well turn his question round and ask where will he find a professor who can teach the *highest* mathematics to technical students, and who is at the same time a practical engineer? Here Klein comes in; his plan will help to educate such men.

Riedler has in these papers a fling at higher mathematics as cultivated at the Universities, where "Abel and Riemann" count much, where one lives in regions in which θ-functions disappear, and in hypo- or meta-geometry, where "dimensions cease and manifoldnesses begin," and where the student learns "gymnastics in four dimensions."

It is easy from a "practical" point of view to make light of many parts of pure mathematics. Even Klein professes that he has often had doubts whether those theories in which the mathematician delights are really worth the trouble of increasing and developing, and in his opinion they would not be if they should never be of use in application to physical and engineering problems.

But, he adds, he has always come away from such contemplations with the conviction that his (and all mathematicians') optimistic views are justified by the belief that they will assist in due time in subjugating nature to science. In fact, the history of science is so full of examples that it is unnecessary to quote any.

If Riedler should succeed in getting the influence of all those speculations banished from the Hochschule, these will soon become as fossilised as the Universities, in his opinion, are at present.

But let us return to Klein's plans. His chief idea, as gathered from the various papers and from his own expressions during his recent visit to England, can be stated briefly enough.

He wants to bring together again theory and practice; he wishes the Universities to take their proper place in modern German life, which differs from that of former days by its enormous energy in industry and commerce. He acknowledges that much has been done outside the Universities, and for purely practical purposes, to develop science; that altogether new methods of investigation have been invented by engineers, and not only in physical investigation but even in mathematics.

He wishes to introduce these at the Universities to enable them to fulfil their duties properly, and he hopes by thus raising these institutions to enable them so to develop science that the results will be practically useful and repay the debt to engineers which science now owes them.

But he also hopes greatly to improve the education of mathematical and science teachers. There can be no doubt that the chief education of these must and will remain in the hands of the Universities—that they cannot be left to the technical schools. It is quite impossible to establish schools exclusively for future engineers, because it is impossible to settle at an early age what career a boy will select, and the majority of schools must be of a general character.

But what is highly desirable is that all teachers, not only the scientific ones, should be better prepared in science, and should gain a higher idea of the value of practical work, and that the old spirit according to which education can only be gained through the old languages, should be broken.

Not only the would-be engineers, but all boys must be made to feel this change, and therefore all teachers must be imbued with modern notions. To have some educated at the University and some at the technical schools would intensify the existing antagonism between science and classics. This ideal education of teachers can only be obtained at the Universities, and here only if these are themselves modernised. Klein's scheme tends to bring this about; it does not exclude the possibility of some teachers of science and mathematics being educated at high schools, nor that many of these should spend a part of their time in studying at a high school; it would be easy to devise a plan by which this could be accomplished.

Klein also hopes to help the engineer directly. The problems taken up by University men are at present without direct connection with practical needs, simply because the latter are unknown at the Universities. Klein wants to make these needs known to the University teachers in order to make it possible to direct their energies in the channels useful to engineers. Again, by having at hand a technical laboratory, and having connected with this all the intellectual resources of the University, it will be possible to bring to bear on technical problems such scientific power as is not likely to be found elsewhere.

To the same end he wishes to make important English scientific papers on technical subjects accessible to German physicists and engineers through translations, and a beginning will be made with Prof. Osborne Reynolds' paper on "Friction of Lubricated Bearings." Dr. Routh's "Rigid Dynamics" will also be translated.

It will be seen from this that Klein's scheme does not affect the ordinary education of engineering students, but that he takes a far higher flight which will not affect the routine at the high schools. Indirectly it cannot fail to raise the whole profession, the whole education of Germany; and if it is carried out in the spirit in which it is conceived, and is ably supported by his colleagues, it will have far-reaching consequences.

That the original memorandum did not reveal the full meaning of Klein's scheme can be explained by supposing that he had himself suffered from the want of direct contact with the engineering profession, and, besides, by his taking it for granted that every one would understand that he was speaking only of the *highest* part of the education of engineers, and that he did not dream of establishing a new engineering school to compete with the old ones.

As soon as he became aware of the opposition raised, he tried by personal intercourse to put himself right, and to destroy the false impression originally created. He went to meetings of the Engineer's Verein at Aachen and Hanover, in 1895, and expounded his plans, with the result of converting many to his views. When he found that the high schools were preparing schemes for laboratories of their own, he at once gave up all idea of asking the Government for money, considering that here the high schools had the first claim, and set about to make private means available in English and American fashion. He succeeded in interesting influential and wealthy manufacturers in his cause, who formed a committee which has promised and guaranteed him a sum sufficient to start one laboratory. For this purpose the thermodynamic laboratory has been selected, and is now in course of erection. As to the choice of a director, he has asked Prof. Linde's advice, who has recommended a pupil of his own; and all will agree that Linde's name is sufficient guarantee that the new director has been educated in a truly practical spirit.

Prof. Klein's plan does not in the least collide with the legitimate aims of the technical high schools; such collision only takes place with regard to the education of teachers, and here the claims of Riedler and others seem to us to be altogether unreasonable.

Klein is altogether the right man to carry out the plan successfully. His singleness of mind is conspicuous to every one who has come, however slightly, in contact with him. As a mathematician he is known and honoured all the world over. He possesses a strong faculty for geometrical conceptions, and likes, with wonderful success, to clothe every mathematical investigation in a geometric garb, or to illustrate it geometrically. His book on the *Ikosaeder* is a brilliant example of this. He, more than any other, has tried to remain in contact with the school teachers of mathematics, and has often put the results of profound mathematical speculations in such a form that they become available for school teaching.

To make the teaching of geometry more real he started, when Professor at the Munich Technical High School, the modelling of surfaces by the students; and the whole large collection of models on sale by Brill in Darmstadt may be said to have grown out of this. For the same reason, he has introduced at the University a course of geometrical drawing. He dwells not less on the necessity of developing facility in performing arithmetical calculations.

All engineering teachers in England will wish that English schoolmasters had been drilled in these two directions.

By descent, and from the environments in which he grew up, he has, from his youth, been familiarised with industry and manufacture.

The traditions of Göttingen, too, are greatly in his favour, and have helped to ripen his plans. Here Gauss worked for years at all possible problems ranging from pure abstract theory of numbers to the invention of an electric telegraph, and of a method of signalling by the sun's rays, now so extensively used in the English army. He enriched science as well as engineering with many important gifts; the theory of least squares, the absolute measure of force, the theory of magnetism, and all his work in connection with Weber.

What Gauss did alone, that Klein wishes to continue in combination with others; he justly observes, also, that a small town is more suited for his experiment than a large town with all its distractions.

We can only wish him success in his bold undertaking, and feel sure that, even if German engineers should carry their antagonism so far as to try to starve his undertaking by preventing young men from making use of the opportunity he offers them, which is most improbable, there will come to him, as heretofore, many eager students from England and America. O. Henrici.

A WELL-KNOWN TEXT-BOOK OF CHEMISTRY.

A Manual of Chemistry, Theoretical and Practical (based on Watts' edition of Fownes' Manual). By William A. Tilden, D.Sc., F.R.S. Pp. xvi + 599. (London: J. and A. Churchill, 1897.)

THE preface to the original edition of Fownes' *Manual* is dated October 5, 1847. The merits of that book, published about half a century ago, were known to all. But, inasmuch as Prof. Tilden says in his preface to the present work "the last traces of Fownes have disappeared in the process" of re-writing, it is a manual of chemistry by Dr. Tilden, and not Fownes' book, that is to be reviewed here.